Projected increases in drilling and completion costs (JAS) indicate a total cost of $179 billion. *Not included* are lease, geologic and geophysical, development-well, and overhead costs.

A projected increasing role of natural gas and NGL in the total energy mix results from the relatively large proportion of gas, on a Btu equivalent basis, being discovered/foot of new-field wildcat drilled. At present finding rates it is not possible to replace the 7.0×10^9 BOE annual production.

Projected costs are so large that attainment of these limited goals does not seem possible. Total cost of the necessary new-field wildcats ($179 billion), however, is in the same order of magnitude as President Carter's estimated federal income from the "windfall" profits tax for 1980 to 1990. In any case, estimates of available oil and gas resources indicate that it *is* possible to moderate the decline in reserves and production.

HULSE, WILLIAM J., Bass Enterprises Production Co., Denver, Colo.

Depositional Environment of Bartlesville Sandstone, Sallyards Field, Greenwood County, Kansas

A facies model of the subsurface Bartlesville Sandstone in Sallyards field, Greenwood County, Kansas, was developed from well-core descriptions, petrographic analysis, electric log examination, and construction of maps and cross sections.

Subsurface mapping indicates that the Bartlesville Sandstone is narrow and elongate in plan view and lenticular in cross section. It displays an asymmetric convex-down base, thickens at the expense of the underlying shales, and is a multistoried sandstone body. Self-potential logs usually show an abrupt basal contact and a blocky or an upright bell-shaped curve. A structure map at the top of the pre-Pennsylvanian surface indicates that deposition of the Bartlesville Sandstone was influenced by underlying structure.

The sandstones are mineralogically and texturally immature with abundant metamorphic rock fragments, micas, clays, angular tourmaline, and feldspar grains. The amounts of clays and micas increase and grain size decreases upward in the sandstone as shown by thin-section measurements. Biogenic material includes abundant wood fragments and organic matter in the conglomerate zones.

Core studies reveal a vertical sequence for the Bartlesville Sandstone consisting of a sharp basal contact, large-scale cross-bedding, massive bedding or conglomerate zones, unidirectional current ripples, and a gradational or sharp upper contact with overlying siltstone. The scale of sedimentary structures decreases upward. The laterally associated facies consist of dark-gray to black shale, greenish-gray shale, ironstone, underclay, coal, and limestone.

Comparison of the described facies model with process-response models of modern depositional environments indicates that the Bartlesville was deposited by a perennial, fine-grained, meandering, alluvial stream following lows on the eroded pre-Pennsylvanian surface. The associated facies were deposited in a delta-plain to shallow-marine environment. Enclosure of the sandstone bodies in oil-rich shale and later structural movement led to favorable conditions for the development of combination structural-stratigraphic traps.

Previous regional work, checked by log correlation across Kansas, suggests that the Bartlesville Sandstone in Sallyards field is laterally equivalent to the surface Bluejacket Sandstone.

KASINO, RAYMOND E., and DAVID K. DAVIES, Texas Tech Univ., Lubbock, Tex.

Environments and Diagenesis, Morrow Sandstones, Cimarron County, Oklahoma

Detailed investigations of Morrow Sandstones in Cimarron County, Oklahoma, provide a bird's-eye view of problems encountered during regional exploration, production, and completion practices over a wide area from New Mexico to Kansas. The generally poor lateral and vertical control of sand distribution can be improved through a detailed knowledge of environments of deposition. Frequent formation damage because of poor completion procedures can be largely prevented through an understanding of Morrow sandstone diagenesis.

Morrow sandstones in Cimarron County form two distinct reservoirs. Type 1 reservoirs are thick (10 to 50 ft or 3 to 15 m), porous (20 to 23%), permeable (47 to 236 md), and very coarse grained (0.83 mm). These reservoirs are fan-shaped, being less than 1 mi (1.6 km) wide at the apex (on the northwest) and 4 mi (6.4 km) wide at the southeastern edge. Sand thickness is greatest at the center of the body. These sands were deposited in the estuarine portions of a braided fluvial system.

Type 2 reservoirs are thin (generally less than 20 ft or 6 m), have relatively low porosities (4 to 20%) and permeabilities (3 to 100 md), and are fine grained (0.24 mm). These reservoirs are discontinuous, lenticular, elongate units which trend at approximately right angles (NE-SW) to the Type 1 reservoirs. Maximum width is 1 mi (1.6 km); maximum length is of the order of several miles. These sands were deposited in lower tidal-flat and shallow, offshore-marine environments, as beaches and bars.

Once the reservoir has been discovered, it is vital that completion practices be tailored to the specific rock composition. Failure to do this may result in serious formation damage, and the bypassing of potential production. Problems characteristic of these sands include: (1) a migration of fines, (2) extreme acid sensitivity, and (3) possible water sensitivity. The sand composition may often require a multistage acid job with KCl flushes. Hydrofluoric acid should not be used unless the detailed sand composition has been determined by thin-section analysis.

LIPSTREUER, KENNETH A., and COLIN BARKER, Univ. Tulsa, Tulsa, Okla.

Geochemistry of Small Lacustrine Delta, Great Salt Plains, Alfalfa County, Oklahoma

A shallow lacustrine delta is forming at the northern end of the Great Salt Plains reservoir in Alfalfa County, north-central Oklahoma. Although sediment is supplied solely by the river, organic matter may be derived from the land surface (and transported by the river) or derived from the lake itself. The total amount of organic carbon in the surface sediments increases with distance from the river mouth and is accompanied by a decrease in mineral grain size as expected. However, within a single sediment sample, organic carbon content is not a strong function of grain size over the range from 5 to 11ϕ. Visual examination of the separated insoluble organic matter showed that structured, wood-derived organic matter predominates in the coarser fractions ($>62\mu$) but the finer fractions ($<62\mu$) contain mainly microorganisms and amorphous material. Pyrolysis experiments gave a ratio of (total response/organic carbon content) that increased from low values in the coarse fractions to higher values in the fine ones—a trend consistent with the visual kerogen observations because high ratios are usually produced by amorphous organic matter. However, infrared spectra of the organic matter from coarse and fine sediments closely resemble that generally observed for the humic substances associated with soils, suggesting that even the finer grained, amorphous organic matter is derived largely from the terrestrial organic matter. X-ray diffraction indicated the presence of quartz, feldspars, calcite, dolomite, mica, kaolinite, illite, and montmorillonite in the sediments. The composition was rather uniform with no major variations due to clay size or areal distribution.

RASCOE, BAILEY, JR., and FRANK J. ADLER, Phillips Petroleum Co., Bartlesville, Okla., and Denver, Colo.

Controls on Pennsylvanian Hydrocarbon Accumulations in Mid-Continent

Approximately 8.8 billion bbl of oil and about 31.5 Tcf of gas have been found in Pennsylvanian reservoirs in the Mid-Continent as of January 1, 1978. Although these volumes of hydrocarbons were trapped in thousands of fields throughout the region, most of these resources were emplaced in a relatively few fields: about 6.4 billion bbl of oil has been found in 90 significant and giant oil fields, and 18.5 Tcf of gas has been discovered in 50 significant and giant gas fields. Our calculations of the total oil and gas accumulations in Pennsylvanian reservoirs were extrapolated from these data.

Most oil and gas accumulations of Pennsylvanian age in the Mid-Continent were stratigraphically trapped in lenticular sandstone bodies; the environments in which most of the clastics were deposited range from fluvial to deltaic to shallow marine. Even though this region is now in a late mature stage of exploration and development, important stratigraphic accumulations of oil and gas remain to be found. These fields will be discovered through detailed subsurface analysis, the reconstruction of depositional environments, and the application of high-resolution seismic data to stratigraphic problems.

SHELBY, JERRY M., Amarillo Oil Co., Amarillo, Tex.

Upper Morrow Fan-Delta Deposits of Anadarko Basin

The Pennsylvanian upper Morrow fan delta chert conglomerates are located in the Texas Panhandle and Oklahoma parts of the Anadarko basin. The source area for these chert conglomerates was the Amarillo–Wichita Mountain complex where erosion of cherty limestones and dolomites of Mississippian age occurred. The presence of these chert conglomerates in the upper Morrow sequence precisely defines a time of uplift and erosion of the highlands not previously recorded and therefore provides a new time-stratigraphic marker for the Morrow. Unusually high porosity and permeability in the chert conglomerates at depths greater than 15,000 ft (4,572 m) in a reservoir which may contain a billion cubic feet of gas per net foot of porosity are adequate incentives and justification for deeper drilling in the basins. Successful efforts in the search for these stratigraphic traps have resulted at Shreikey, Buffalo Wallow, Viking, Cheyenne, Elk City, and other fields.

SIMON, D. E., and R. G. PARKER, Halliburton Services, Duncan, Okla.

Stimulation Design for Upper Morrow Reservoirs in Reydon-Cheyenne Area, Western Oklahoma

Recent deep, high-pressure upper Morrow reservoir completions in the western Oklahoma part of the Anadarko basin indicate the area to be a major natural gas producing area. These Morrow sandstone reservoirs consist of poorly sorted medium to coarse-grained feldspar-rich sandstones to chert-pebble conglomerates. Diagenetic minerals present include calcite, siderite, and quartz overgrowths. Clay minerals present include small to moderate amounts of iron-rich chlorite, mixed-layer clays, and illite. Generally, the diagenetic minerals and the clays tend to fill the intergrain pore space. Reservoir porosity ranges from 6 to 12%, and effective reservoir permeabilities range from 0.1 to 10 md.

Wells are generally drilled to total depth, logged, and a 5-in. (12.7 cm) OD liner is cemented back to the intermediate casing. Once perforated and cleaned up, the well is allowed to flow and a pressure buildup test is performed. Buildup-test analysis commonly indicates that a fracture-stimulation treatment may be needed to obtain satisfactory production rates. With bottom-hole temperatures in excess of 260°F (127°C), potassium chloride treated water in a cross-linked gel system is being used as the treatment fluid. Use of high-strength proppant instead of sand appears to help provide sustained production increases after fracturing.

Treatment designs must consider the following parameters: depth, bottom-hole temperature, reservoir pressure, and bottom-hole treating pressure, as well as surface-pressure limitations, tubing size, job volume, and type of proppant system used with respect to closure stresses expected.

Following the stimulation treatment and fluid cleanup, another pressure-buildup test is performed to evaluate the treatment. Field results indicate that stimulation treatments have been successful.

SWANSON, DONALD C., Exxon Production Research Co., Houston, Tex.

Deltaic Deposits in Upper Morrow Formation of Anadarko Basin

Environmental facies analysis of Pennsylvanian upper Morrow deposits of the Anadarko basin show a variety of deltaic facies. The important reservoir deposits